

10/588401

FIN 575 P/200354795

IAP11 Rec'd PCT/PTO 03 AUG 2006

Description

Semiconductor component comprising a semiconductor chip  
5 stack on a wiring frame and method for producing the  
same

The invention relates to a semiconductor device having  
a semiconductor chip stack on a rewiring plate which  
10 bears the semiconductor chip stack on its top side and  
has a rewiring structure which is electrically  
connected to the contact areas of the semiconductor  
chips in the semiconductor chip stack. The invention  
also relates to a method for producing such a  
15 semiconductor device.

The document US 5,973,403 discloses such a device for  
stacking two semiconductor chips which are intended for  
multichip modules (MCMs) and can be inserted into  
20 memory modules which have components fitted on one side  
(SIMMs, single in-line memory modules) or into memory  
modules which have components fitted on two sides  
(DIMMs, dual in-line memory modules). To this end,  
these memory modules have a base in the form of a  
25 printed circuit board. This printed circuit board has a  
rewiring structure on which contact pads for flip-chip  
contacts and contact pads for bonding wire connections  
are arranged.

30 In this prior art, the semiconductor chip stack is  
formed by a semiconductor chip having flip-chip  
contacts and a semiconductor chip having contact areas  
which can be bonded being stacked in such a manner that  
their rear sides rest on top of one another. In this  
35 case, the flip-chip contacts are directly connected to  
the rewiring structure and the stacked semiconductor  
chip is coupled to the rewiring structure via bonding  
wires, the associated contact pads for the

semiconductor chips been joined together on the printed circuit board via rewiring lines.

One disadvantage of such a device resides in the fact  
5 that, after the electrical connections have been produced, the semiconductor chips in the semiconductor chip stack can only be tested together. The indication of a fault during testing thus does not provide any reliable statement as to which of the devices has  
10 caused a technical failure since the fault can no longer be unambiguously assigned. This disadvantage makes manufacturing analyses, fault frequency investigations and process optimization more difficult since, after bonding, only statements regarding the  
15 properties of the stack are possible. Unreliability in the contact-connection cannot be assigned either to an individual bonding connection or to an individual connection with a flip-chip contact.

20 The document US-6,071,754 discloses a way of stacking two semiconductor chips which is similar to the document US-6,007,752. In order to connect contact pads of the two types of semiconductor chip, the underside of the semiconductor plate is provided with a further  
25 rewiring structure in that case. In addition, provision is made of through-contacts to this rewiring structure on the underside. Nevertheless, the problem of the semiconductor chips which are connected to the rewiring structures on the top side and underside of the  
30 rewiring substrate or printed circuit board no longer being able to be tested individually is not solved.

It is an object of the invention to provide a semiconductor device which has a semiconductor chip  
35 stack and in which, after the individual semiconductor chips in the semiconductor chip stack have been connected to the rewiring structures of a rewiring substrate, the functions of the individual

semiconductor chips can also still be tested and malfunctions can be unambiguously assigned without interfering with the manufacturing costs, so that increased reliability of semiconductor devices having  
5 semiconductor chip stacks is achieved with the same manufacturing outlay.

This object is achieved by means of the subject matter of the independent claims. Advantageous developments of  
10 the invention emerge from the dependent claims.

The invention provides a semiconductor device having a semiconductor chip stack on a rewiring plate. The underside of the rewiring plate simultaneously forms  
15 the underside of the semiconductor device in this case. At least one external contact area having a plurality of external contact area regions which are physically separate from one another is arranged on this underside. The individual external contact area regions  
20 are assigned to the individual semiconductor chips in the semiconductor chip stack. The external contact area regions (which are physically separate from one another) of an individual external contact area are electrically connected via a common external contact.

25 This semiconductor device has the advantage that, before external contacts are applied to the external contact area regions of an individual external contact area of each semiconductor chip in the semiconductor  
30 chip stack within the semiconductor device, can be individually tested. In this case, the number of semiconductor chips is not restricted to two semiconductor chips in the stack but rather, depending on the size of the external contact area, a plurality  
35 of external contact area regions which are physically separate from one another can be provided in order to individually test a correspondingly large number of semiconductor chips in a semiconductor chip stack.

The size of a measurement probe also decides the possible number of semiconductor chips which can be stacked since the spatial extent of the measurement probe provides a minimum size for each of the external contact area regions. Given the currently available miniaturization of measurement probes and the technically expedient sizes of external contact areas, up to six external contact area regions of an external contact area can be physically separated from one another, with the result that up to six stacked semiconductor chips can be individually tested using the external contact area regions after the semiconductor device has been completed. External contacts can only be fitted after the test but the operation of fitting external contacts to physically separate external contact area regions is technically less problematical than the operation of internally wiring contact areas of semiconductor chips to corresponding rewiring structures of a rewiring printed board.

In one preferred embodiment of the invention, the rewiring plate has, on its top side, a rewiring structure which, in its center, has contact pads for connecting a semiconductor chip to flip-chip contacts. The edge region of the rewiring plate, which surrounds the center, may have contact pads for bonding connection to one or more stacked semiconductor chips. Dividing the associated external contact areas on the underside of the rewiring plate into a plurality of external contact area regions of a single external contact area advantageously makes it possible both to inspect each individual flip-chip contact using the associated contact pads and to test each individual bonding connection if the bonding connections and the chip stack have already been embedded in a plastic

housing composition on the top side of the rewiring plate.

Another advantage of such a semiconductor device is  
5 that it has a very compact chip stack because the rear side of the stacked semiconductor chip, which is to be provided with bonding connections, can be positioned on the rear side of the first semiconductor chip having flip-chip contacts. Such a technique makes it possible  
10 to approximately double the storage capacity both of a SIMM module and of a DIMM module.

In another embodiment of the invention, the rewiring plate has, in the center of its top side, a rewiring structure for fitting a rear side of a lower semiconductor chip. The rewiring structure also has, in the edge regions of the rewiring plate, contact pads for bonding connections to the top sides of the stacked semiconductor chips and of the lower semiconductor chip. This type of stacking, which begins with the rear side of a semiconductor chip, takes into account the fact that the next higher semiconductor chip stacks have a smaller circumference and a smaller active top side with contact areas, with the result that it is  
20 possible to interleave the semiconductor chips in the semiconductor chip stack, it being possible to access the edge regions of the respective top sides of the semiconductor chips and the contact areas arranged there.  
25

30 In this type of stacking, it thus becomes possible to provide a bonding connection from the contact areas of the semiconductor chips in the semiconductor chip stack to the rewiring structure of the rewiring plate and,  
35 from there, to reach the underside of the rewiring plate and finally individual external contact area regions via rewiring lines of the top side of the rewiring plate and via through-contacts. The individual

associated semiconductor chips can be individually tested using said external contact area regions. In this case, the through-contacts of the rewiring plate are used to connect the contact pads on the top side of 5 the rewiring plate to the external contact area regions on the underside of the rewiring plate.

Rewiring lines which can be provided both on the top side and on the underside of the rewiring plate 10 respectively lead to the through-contacts in order to ensure that external contact area regions are connected to the associated or corresponding contact pads of the individual semiconductor chips.

15 The semiconductor chips in a stack have, on their active top sides, contact areas which are connected, via flip-chip contacts and/or bonding connections, to the contact pads on the top side of the rewiring plate. The previous technologies can be used for such a 20 bonding connection, the inventive semiconductor device having the advantage that each individual bonding connection of these bonding connections can still be tested after the bonding connections have been embedded in a plastic housing composition.

25 Another aspect of the invention relates to a panel or a rewiring substrate strip which has device positions which are arranged in rows and columns and have 30 semiconductor devices. These semiconductor devices are patterned in such a manner that they have chip stacks in the semiconductor device positions on the top side of the panel, said chip stacks being connected to a rewiring structure on the top side of the panel via corresponding connections and having, on the underside, 35 external contact areas which form external contact area regions which are physically separate from one another and correspond to the semiconductor chips in the semiconductor chip stack of the semiconductor device.

Such a panel has the advantage that a standard plastic cover which covers a plurality of semiconductor device positions can be applied to the panel simultaneously for a plurality of semiconductor devices. After a  
5 plurality of semiconductor device positions have been covered with plastic, it is still also possible to individually test the individual semiconductor chips in a stack of semiconductor chips on the panel or rewiring substrate strip.

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A method for producing and testing a panel having semiconductor devices which are arranged in rows and columns and have semiconductor chip stacks has the following method steps.

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A circuit carrier having rewiring lines which are electrically connected, via through-contacts and contact pads on the top side of the circuit carrier, to external contact area regions on the underside of the  
20 circuit carrier is first of all produced in the form of a rewiring plate. To this end, the external contact area regions are patterned in such a manner that a plurality of external contact area regions are provided for the purpose of fitting an individual external  
25 contact. To this end, the external contact area regions are fitted such that they are physically separate but are not close to one another so that an individual external contact can electrically connect them to one another.

30

After a circuit carrier which is patterned in this manner has been produced, a stack of semiconductor chips is applied to the circuit carrier with connection of contact areas of the semiconductor chips to contact  
35 pads on the top side of the circuit carrier. The circuit carrier can then be covered with a plastic composition in the region of the semiconductor device positions. This covering has the advantage that, in the

subsequent testing method, the sensitive electrical connections between the rewiring structure of the rewiring plate and the individual semiconductor chips in the semiconductor chip stack have already been  
5 solidly protected by the plastic cover. The individual semiconductor chips in a semiconductor chip stack are then tested using the corresponding external contact area regions on the underside of the circuit carrier. On account of the special pattern of the physical  
10 arrangement of the external contact area regions, each individual semiconductor chip of the semiconductor chips can be individually tested from the underside of the panel. After testing, the defective semiconductor devices can be marked in order to individually inspect  
15 them and their faults.

In order to then produce semiconductor devices from this tested panel, further steps are required. After the panel has been produced in the manner described  
20 above, external contacts are applied to the external contact area regions with electrical connection of the external contact area regions. The panel is then separated into individual semiconductor devices. The advantage of producing semiconductor devices having  
25 semiconductor chip stacks in this manner can be seen in the fact that, despite a plurality of semiconductor chip stacks being packaged in one panel, it becomes possible to individually test each individual semiconductor chip in order to implement more accurate  
30 fault analyses in the case of functional faults.

In summary, it can be established that the present invention makes it possible to subsequently connect stacked semiconductor chips. In particular, the  
35 invention results in devices for a so-called ball-grid array (BGA) design. In this BGA design, the semiconductor device has, on its underside, a grid-like arrangement of external contacts in the form of solder

balls, solder beads or solder bumps. The underside having the external contacts is carried by a rewiring plate on which a stack of semiconductor chips may be situated, it being possible for said semiconductor  
5 chips to be arranged differently in this invention.

A combination of a wide variety of semiconductor chips and the external contacts may thus be connected to the rewiring plate. These semiconductor chips in a stack  
10 may be based on flip technology and/or on semiconductors with a bonding wire connection. A stack may also have solely semiconductor chips which are based only on bonding wire connections. It is also possible to provide semiconductor chips which are  
15 stacked by being arranged next to one another on their side edges and being connected to the external contacts of the rewiring plate via the side edges. These different constructions are also referred to as a flip-chip wire bond stack, a wire bond/wire bond stack  
20 and/or a side-by-side multichip package (SSMCP) in semiconductor technology.

In this case, the invention advantageously makes it possible for the electrical connection to the external contacts to be configured in such a manner that,  
25 despite the semiconductor device having been completed, the chips are not yet electrically connected to one another and can thus be electrically tested individually from outside the underside of the  
30 semiconductor device. These connections of the individual lines to the individual chips are only realized via the external contacts in the form of solder balls, solder beads or solder bumps. This has the following advantages:

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1. First of all, the semiconductor chips can be electrically tested completely separately from one another without said chips influencing one

another. By way of example, a baseband chip and a DRAM chip or an analog chip and a digital chip can thus be tested in a manner such that they are completely insulated from one another and can be  
5 individually tested even though they have already been completely packaged in the device housing. The testing operation may even be carried out on a panel or a substrate strip, on which a plurality of devices are present in groups under a plastic cover, even before this substrate strip or the  
10 panel is separated into individual semiconductor devices.

2. It is also possible to finally implement different  
15 options for the semiconductor device only when the external contacts are being applied to the external contact area regions of the invention. To this end, an external contact is either applied and a connection is thus established between the  
20 semiconductor chips or this external contact is then omitted for another function. By way of example, particular functions of a multichip system may thus be enabled only when external contacts are fitted or are not fitted to the  
25 inventive external contact regions. A particular operating state of a chip may thus be achieved, for example, when common external contacts are used, for example in the case of a DRAM which is intended to be operated in different modes, for  
30 example in a x4, x8, x16 or x32 mode.

The invention will now be explained in more detail with reference to the accompanying figures.

35 Figure 1 shows a schematic plan view of a rewiring plate of a semiconductor device according to a first embodiment of the invention for stacking two semiconductor chips;

5 figure 2 shows a schematic plan view of a rewiring plate of a semiconductor device according to a second embodiment of the invention for stacking four semiconductor chips;

10 figure 3 shows a schematic plan view of a rewiring plate of a semiconductor device according to a third embodiment of the invention;

15 figure 4 shows a schematic plan view of a rewiring plate having stacked semiconductor chips according to figure 3;

20 15 figure 5 shows a schematic cross section through a semiconductor device having a semiconductor chip stack according to the first embodiment of the invention shown in figure 1, with the possibility of individually testing the stacked semiconductor chips in the semiconductor chip stack;

25 figure 6 shows a schematic cross section of the semiconductor device according to figure 5 after external contacts have been fitted to the underside of the semiconductor device.

30 Figure 1 shows a schematic plan view of a rewiring plate 2 of a semiconductor device according to a first embodiment of the invention for stacking two semiconductor chips. The plan view depicted in figure 1 is only a partial view of the top side 25 of the rewiring plate 2. Solid lines are used to illustrate the rewiring structures 15 on the top side 25 of the rewiring plate 2 in figure 1. Dashed/hatched areas are used to show the rewiring structures on the underside of the rewiring plate 2. Two types of contact pads 16

and 20 are therefore illustrated on the top side 25 of the rewiring plate 2.

The larger contact pads 20 are arranged in an edge  
5 region 17 of the top side 25 of the rewiring plate and  
are used to fit bonding wire connections. In the  
present case, they have a length of approximately  
150  $\mu\text{m}$  and a width in the range from 70 to 100  $\mu\text{m}$  in  
order to hold correspondingly thick bonding wires on  
10 the contact pad 20. In contrast, the contact pad 16  
only has a diameter of a few 10 micrometers which, in  
the present case, is approximately 60 to 80  $\mu\text{m}$  and is  
used to connect flip-chip contacts to the rewiring  
structure 15 on the top side 25 of the rewiring plate  
15 2.

Separate rewiring lines 26 lead, from the contact pads  
16 and 20, to through-contacts 24 which electrically  
connect the rewiring structure 15 on the top side 25 of  
20 the rewiring plate 2 to the rewiring structures 15 on  
the underside of the rewiring plate 2. Furthermore, the  
rewiring lines 26 for the contact pads 16 and 20 are  
also separate from one another on the underside of the  
rewiring plate 2. In addition, they are not  
25 electrically connected to one another by means of the  
external contact area 5 which is arranged on the  
underside. Rather, they are connected to physically  
separate external contact area regions 6 and 7 which  
are separated by means of a gap 29. The gap 29 has a  
30 distance  $a$  between an external contact region 6, which  
corresponds to the contact pad 16 for flip-chip  
contacts, and the contact area region 7 which  
corresponds to the contact pad 20 for bonding wire  
connections. The distance  $a$  also electrically separates  
35 the two external contact area regions 6 and 7 from one  
another, with the result that the semiconductor chips  
in the chip stack can be individually tested. After the  
test, a common external contact which provides an

electrical connection can then be applied to the external contact area regions 6 and 7 of the external contact area 5.

5     Figure 2 shows a schematic plan view of a rewiring plate 2 of a semiconductor device according to a second embodiment of the invention for stacking four semiconductor chips. Components having the same functions as in figure 1 are labeled with the same  
10 reference symbols and are not additionally discussed. Figure 2 shows a corner region of the top side 25 of the rewiring plate 2. Three contact pads 20 for fitting bonding wire connections are arranged in this corner region so that it is possible to connect three stacked  
15 semiconductor chips for bonding wire connections via these contact pads 20 to the external contact area regions 7, 8 and 9 on the underside of the rewiring plate 2 via the through-contacts 24.

20    In contrast to the three stacked semiconductor chips, the lowermost semiconductor chip may have flip-chip contacts which are arranged on contact pads 16 for flip-chip contacts, said contact pads being situated under the semiconductor chip stack 1 whose outer  
25 contour is marked by the dashed line 30. Four semiconductor chips in a semiconductor chip stack can thus be tested separately and individually using the external contact area regions 6, 7, 8 and 9 via the rewiring plate 2 of the second embodiment of the  
30 invention according to figure 2, their contact areas (not shown here) being electrically connected to one another only when applying external contacts.

35    Figure 3 shows a schematic plan view of a rewiring plate 2 of a semiconductor device 4 according to a third embodiment of the invention. An edge region 17 of the rewiring plate 2 and the position of the edges 30, 31, 32 and 33 of stacked semiconductor chips 10, 11, 12

and 13 are shown relative to one another in figure 3. Solid lines are used to mark the top side 25 of the rewiring plate 2. A dashed line 30 is used to mark an edge side of a lowermost semiconductor chip 10, this 5 semiconductor chip 10 being applied to the top side 25 of the rewiring plate 2 by material bonding. A dashed line is likewise used to mark a contact area 27 on the top side 23 of the semiconductor chip 10 in figure 3.

10 The edge of the next stacked semiconductor chip 11, which is marked using a dash-dotted line 31, is set back to such an extent that the contact area 27 of the semiconductor chip 10 remains accessible. A bonding connection 21 which is likewise marked using dashed 15 lines may thus be arranged from the contact area 27 of the semiconductor chip 10 to the contact pad 20 on the top side 25 of the rewiring plate 2.

The edge of the next stacked semiconductor chip 12 is 20 marked using a dash-double dotted line 32 and is set back to such an extent that the contact area 27 of the semiconductor chip 11 situated underneath it remains freely accessible. It is thus possible to connect the contact area 27 (marked using a dash-dotted line) of 25 the semiconductor chip 11 to a contact pad 20 via a bonding connection 21 which is marked using a dash-dotted line. The side edge of the fourth semiconductor chip 13 in this stack is marked using a dash-triple dotted line 33 and has, on the semiconductor chip 13, a 30 contact area 27 which is likewise marked using a dash-triple dotted line and is connected, via a corresponding bonding connection 21, to a corresponding contact pad 20 on the top side 25 of the rewiring plate 2. The four contact pads 20 depicted on the top side 25 35 of the rewiring plate 2 are connected, via four through-contacts 24, to the four external contact area regions 6, 7, 8 and 9 of an external contact area 5 on the underside of the rewiring plate 2.

The pattern on the underside of the rewiring plate 2 is again marked using dashed hatched areas. The semiconductor stack is potted in a plastic composition  
5 which is not shown in figure 3, with the result that only the underside of the rewiring plate 2 is accessible for a test. The inventive arrangement of the rewiring structures 15 makes it possible for each semiconductor chip 10 to 13 in the stack 1 of this  
10 semiconductor device 4 to be individually tested even after bonding and even after the plastic composition has been applied.

Figure 4 shows a schematic plan view of a rewiring plate 2 having four stacked semiconductor chips 10, 11, 12 and 13 like in figure 3. Components having the same functions as in figure 3 are labeled with the same reference symbols and are not additionally discussed. The difference from figure 3 is that the lowermost  
20 semiconductor chip 10, whose edge is marked using a dashed line 30, does not require any bonding connections but rather is connected, via flip-chip contacts, to corresponding contact pads 16 which are arranged under the semiconductor chip stack 1 on the  
25 top side 25 of the rewiring plate 2.

The three upper stacked semiconductor chips 11, 12 and 13 are again arranged, with their edge sides staggered, in such a manner that their contact areas 27 can be  
30 connected, via bonding connections 21, to the corresponding contact pads 20 in the edge region 17 of the top side 25 of the rewiring plate 2. The external contact area 5 on the underside of the rewiring plate 2 is again divided into four external contact area regions 6, 7, 8 and 9, the external contact area region 6 being reserved for connection to the flip-chip contacts of the lowermost semiconductor chip 10. The advantage of this type of stacking in figure 4 over the

stacking in figure 3 is that the edge side of the semiconductor chip 11 does not have to be arranged such that it is offset from the edge side of the lowermost semiconductor chip 10, with the result that, with an appropriate stack height, as in figure 3, the uppermost semiconductor chip 13 can have a larger active top side 23 than in figure 3.

Figure 5 shows a schematic cross section through a semiconductor device 4 having a semiconductor chip stack 1 according to the first embodiment of the invention shown in figure 1, with the possibility of individually testing the stacked semiconductor chips 10 and 11 in the semiconductor chip stack 1. The semiconductor chip 10 has an active top side 23 with contact areas 27 which are fitted with flip-chip contacts 18. These flip-chip contacts 18 are partially connected, via through-contacts 24 of the rewiring plate 2, to external contact area regions 6 on the underside 3 of the rewiring plate 2. The rear side 22 of a further semiconductor chip 11 having a top side 23 with contact areas 27 in the edge region of the semiconductor chip 11 is stacked on the rear side 22 of the lower semiconductor chip 10. These contact areas 27 of the semiconductor chip 11 are connected, via bonding connections 21, to corresponding contact pads 20 on the top side 25 of the rewiring plate 2.

The contact pads 27 of the upper semiconductor chip 11 are assigned, via a through-contact 24, to external contact area regions 7 of individual external contact areas 5. The external contact area regions 6 and 7 are electrically separate from one another at a distance a on the underside 3 of the rewiring plate 2, with the result that a continuous gap 29 ensures that the contact areas 27 of the upper semiconductor device 11 can be tested using the external contact area regions 7 and the contact areas 27 of the lower semiconductor

chip 10 can be electrically inspected using the external contact area regions 6. This inspection is also still possible if, as shown in figure 5, the semiconductor chip stack 1 has been potted in a plastic  
5 composition 28.

Figure 6 shows a schematic cross section of the semiconductor device 4 according to figure 5 after external contacts 14 have been applied to the underside  
10 3 of the semiconductor device 4. Components having the same functions as in figure 5 are labeled with the same reference symbols and are not additionally discussed. Applying the external contacts 14 results in the mutually corresponding contact areas 27 of the  
15 semiconductor chip 10 now being electrically connected in the center 19 of the rewiring plate 2 and of the semiconductor chip 11. This electrical connection can also be carried out on a substrate strip having a plurality of semiconductor devices 4 under a common  
20 plastic cover, so that, after the substrate strip has been separated into a plurality of semiconductor devices 4, semiconductor devices which have been accurately tested are available.